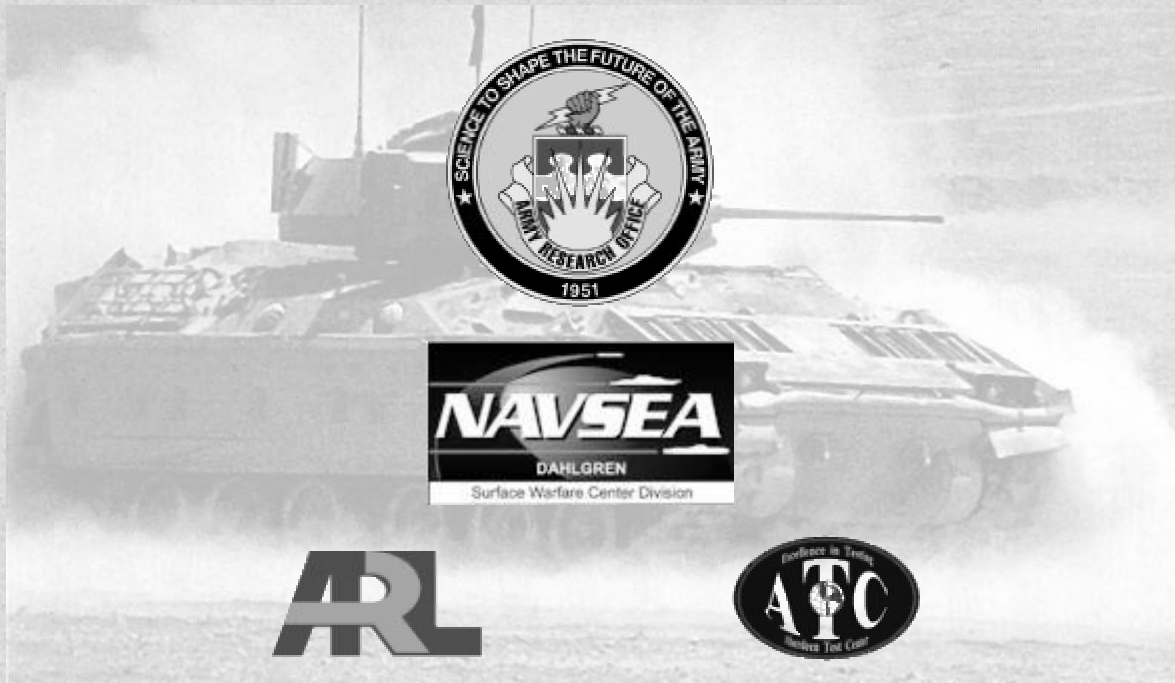




Barrel Armor

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NDIA - Gun & Ammunition Symposium and Exhibition





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SBIR Phase II Grant

“Gun Tube Liner Erosion and Wear Protection”

■ Robert F. Lowey - Prin. Investigator, TPL Inc.

■ Sponsored by Drs. R. Reeber and D. Stepp, ARO



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Barrel Armor
for Future Gun Systems
Robert F. Lowey Senior Engineer and
Program Manager: TPL Inc.



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Phase I SBIR

“Advanced Method for Manufacturing Erosion Resistant Gun Barrels”

- **Funded by the Army Research Office
and Sponsored by Dr. Robert Reeber, ARO**



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Phase I SBIR results:

- Developed a Unique Explosive
- Demonstrated Ta Cladding in 120 MM Smoothbore Tubes





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Phase II SBIR Objectives

- **Transfer 120 mm cladding technology to 25 mm gun barrels and...**
- **Demonstrate feasibility of refractory metal clads in gun barrels by fabricating and field testing to failure a 25 mm gun barrel**



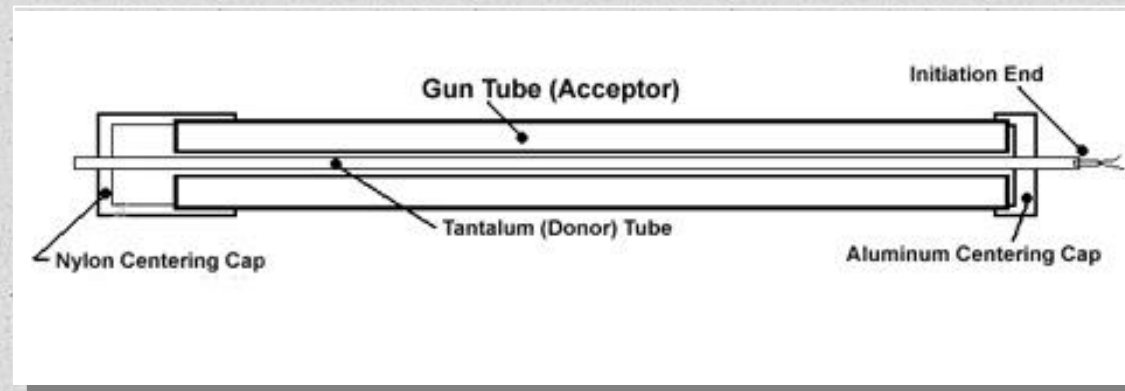
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Phase II

- Development of explosive formulation for small diameter bores
- Development of method for cladding long L/D tubes





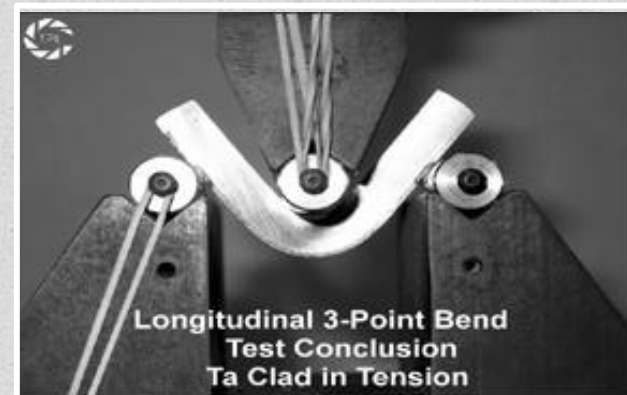
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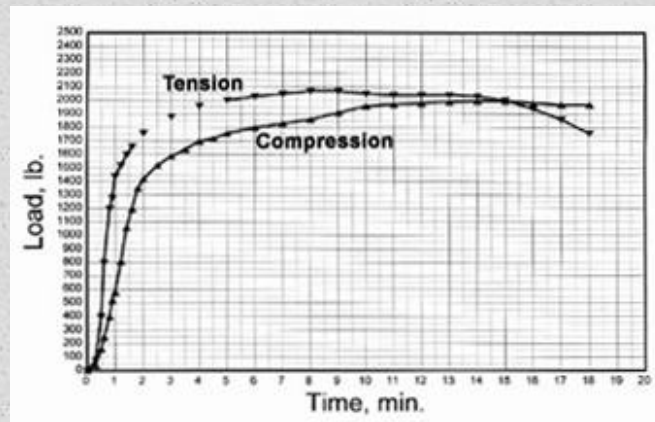


Excellent Bond Strength

- 3 - point bend tests
- Pull out test



Guided Bend Tests





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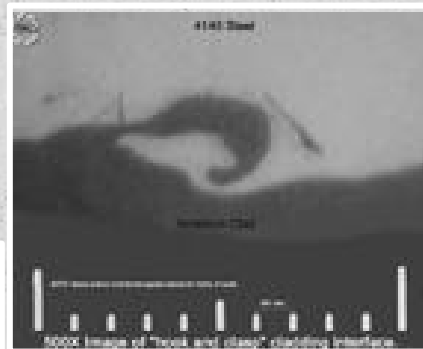
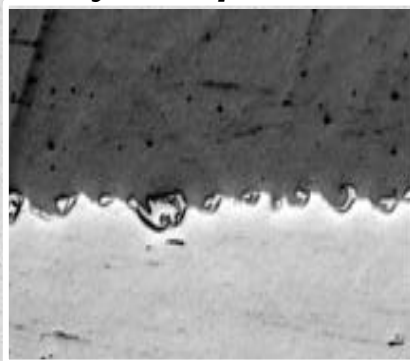


Tailorable Explosive Formulation

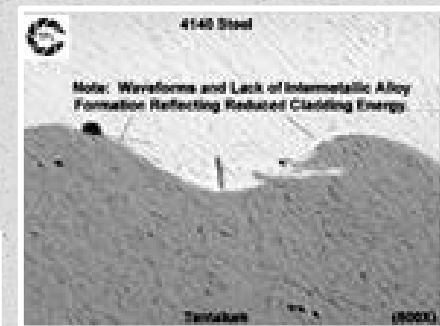
■ Variable energy input
for:

■ Different metals &
thicknesses

Early Interphase



Old waveform



New waveform

■ Control waveform and
interphase alloy creation



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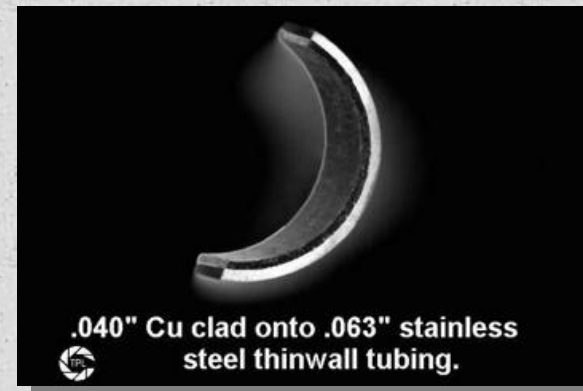


Other Phase II Developments

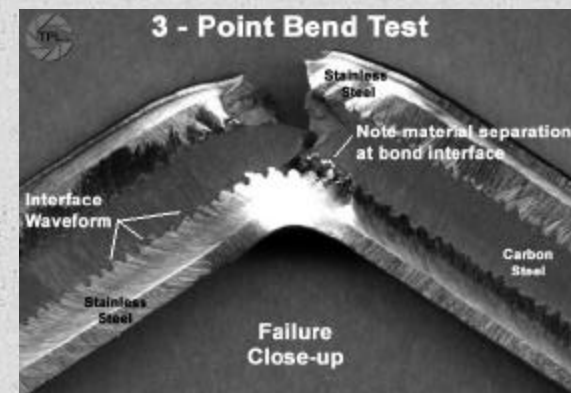
■ Thin-wall Cladding



■ Implosive Cladding - Penetrator Rods



■ Bi-metallic Clads





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Late Program Re-Direction

- **Original Partner had IRAD Funding Shortfall that Would Not Allow for Testing as Planned**
- **Alternative Plan Developed with ARL & NSWC**
 - **Utilize Scrap Bushmaster Barrels**
 - Drs. Reeber & Stepp
 - **NSWC will Fund Testing at ATC**
 - Roger Ellis
 - **ARL will Provide M919 Ammunition**
 - Dr. Jonathan Montgomery

.....





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Test Objectives

- To Test the Erosion Resistance of Tantalum with the Most Erosive Ammunition Available
- Demonstrate the Bond Strength of Explosively Clad Bore Liners by Firing to Destruction



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Test Barrel Design

- Smoothbore Design Selected to Keep Focus on Test Objectives: Erosion Resistance and Bond Strength
- No-Twist Rifled Design Added to Assure Proper Sabot Confinement for Functionality of M919 ammunition
- Design Criteria from Dr. J. Montgomery - ARL

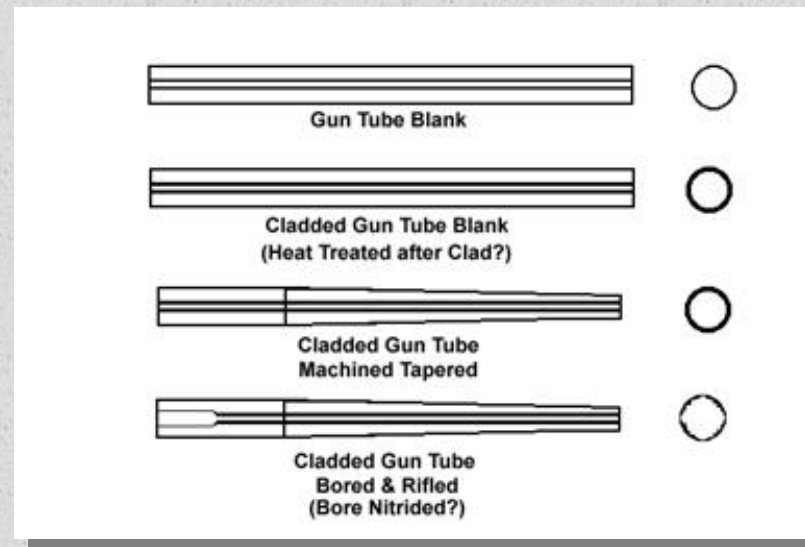


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Test Barrel Design



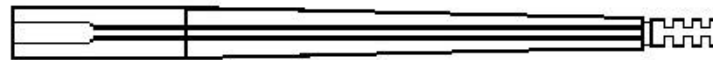
**Explosive Cladding should Occur
Early in Barrel Manufacturing Process**



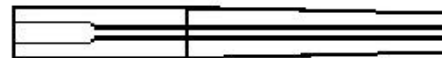
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Test Barrel Design



Standard Bushmaster



**Barrel Truncated
Rifling Removed**



**Barrel Cladded
Honing and Rifling**



Completed Test Barrel

Not Possible Utilizing Existing Barrels



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Test Barrel Design

- Rifling Honed Out to ~ 27.15mm (1.069")
- Tantalum Clad Approximately 1.02mm (0.040")
- Smoothbore Design: Tantalum Honed Down to Wall Thickness of .8mm (0.031")
- Rifled Design: Double Clad
 - Groove - Ta Thickness: .54mm (0.021")
 - Land - Ta Thickness: 1.06mm (0.042")





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Test Barrel Fabrication

- **Ares Inc. Selected for Barrel Honing and Rifling Broaching**

- **Severe Time Restraints Limit Opportunities for Learning Curve for Machining Tantalum**



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Endurance Test Ammunition

■ **M919 (APFSDS-T)**

Lot No. ADJ91D365-002

■ **HES9053 Propellant**
Flame Temp of 3692 K

■ **ATC Obtained 1,985**
Rounds from Primex
for Tests





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Endurance Firing Sequence

- Cycle B Firing Schedule, 150 rounds/Cycle
IAW TECOM 1-WE-100-BUS-050





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***Tantalum Clad 25mm Barrels
Tested March 26-31, 2001
at
ATC, Aberdeen Proving Grounds***



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Test Results

■ Smoothbore Design:

- Fired 1,385 Rounds
- No Significant Increase in Dispersion
- Barrel Still Considered Serviceable



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Test Results

■ **Smoothbore Design:**

- No sign of Tantalum Flaking Off
 - Except Where Undercut by Eroded Gunsteel
- Tantalum Exhibits Heat Checking and Cracking (some severe)
- **No Dimensional Change in 300 Rnds**

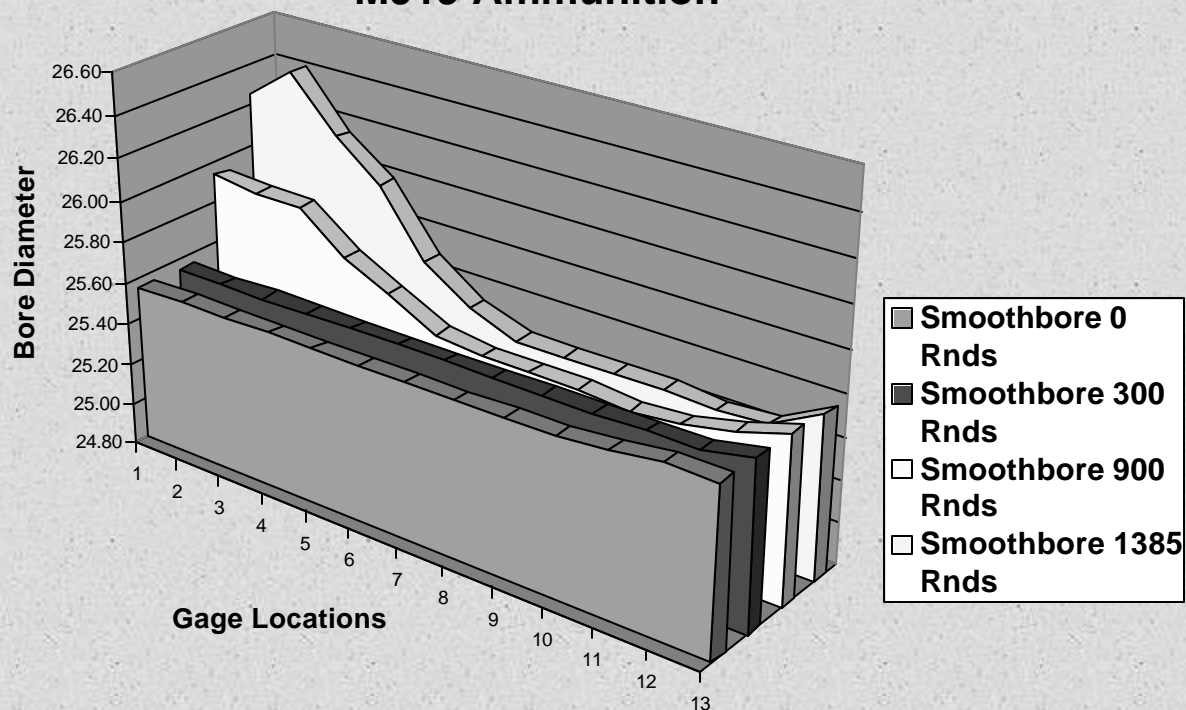


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Smoothbore Test Results

**Smoothbore Bore Wear/Erosion Diameters
M919 Ammunition**





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Test Results

■ Rifled Design:

- Fired 600 Rounds
- No Significant Increase in Dispersion
- Barrel Still Considered Serviceable



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Test Results

■ Rifled Design:

- Double Clad Appears to Have Held Together Well
- No sign of Tantalum Flaking Off
- Bore Wear Data Comparison with APG Tube No. H12373 (1991) ...



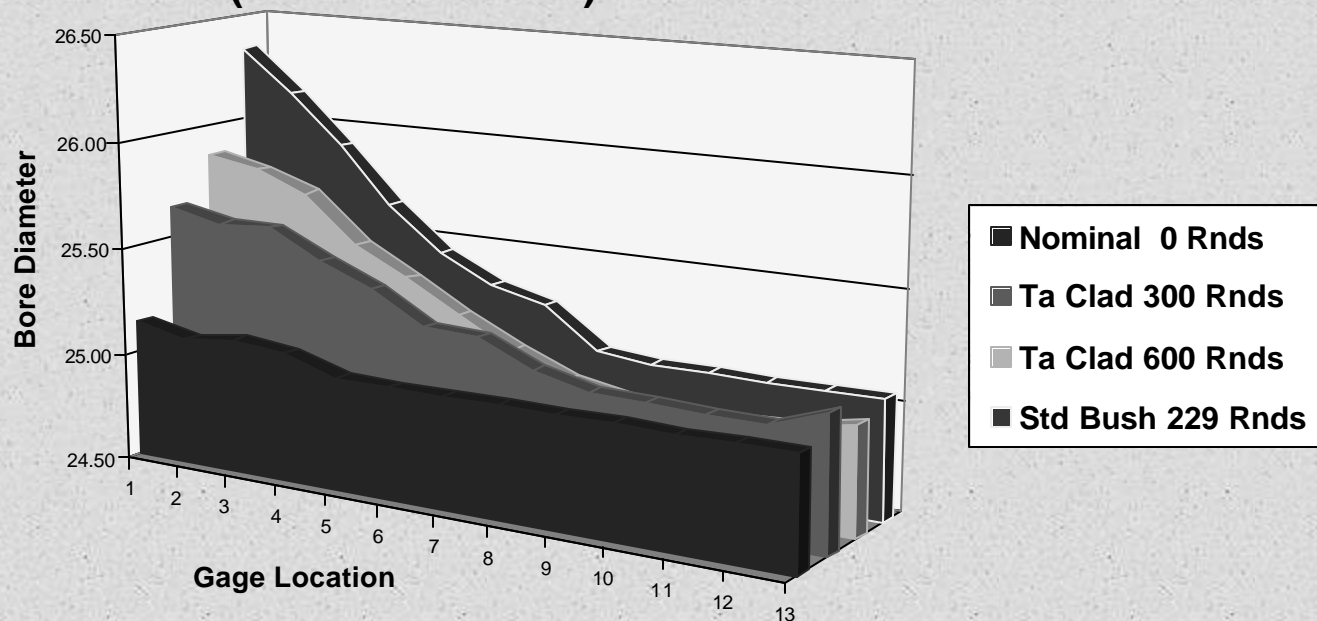
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Rifled Design Test Results

**Bore Wear/Erosion Diameters. Comparison:
Ta Clad (No.C) vs. Std. Nitrided Bushmaster
(Tube No.H12373) with M919 Ammunition**





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Post Firing Analysis Plans

- **Bisect Test Barrels and Section into Specimens**
- **Unfired Reserve Smoothbore and Cut-offs from Test Barrels Available for Comparison**
 - **Microscopic Examinations of Interface and Boundary Conditions, Erosion Features, Etc**
 - **Electron Microprobe Compositional Analysis**
 - **Micro-Hardness Studies**



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Post Firing Analysis Plans con't

- **Sample Specimens *May* be Available for Evaluation at Other Facilities**
- **Pre and Post Test Bore Castings were Prepared by ATC**
- **Post Test Borescope Video was Prepared by ATC**



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Future Developments

- **Trade-Off Studies for Liner Materials**
 - Costs**
 - Erosion Resistance**
 - Hardness**
- **Large Bore Guntube Problems**
 - Rifling Design**
 - Partial Clads**
 - Autofrettage**
 - Fixturing**

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Future Developments

**TPL Inc. Seeks Partners for SBIR
Phase III Program(s) for Insertion
of this Technology into Current and
Future Gun Systems ...**

...the technology is here ...

...and IT WORKS!



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